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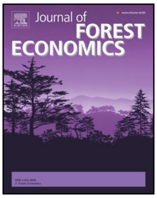

Wood biomass use for energy in Europe under different assumptions of coal, gas and CO_2 emission prices and market conditions

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ABSTRACT

This study examines the effects of different coal, natural gas and carbon emission prices and market situations on the use of wood for electricity and heat production in the European Union. The analysis is carried out using the global forest sector model EFI-GTM expanded to cover electricity and heat production from wood, coal, natural gas, wind and solar energy. Analysis shows that with low coal and gas prices, use of wood for energy will be limited to low cost logging residues. With high coal, and especially natural gas prices, industrial wood also comes to be used for energy. At a carbon price of 100 €/tCO_2, some 32 Mm^3 of industrial wood, in addition to 224 Mm^3 of logging residues, are projected to be used for electricity and heat in the EU region (including Norway and Switzerland) in 2030. The relatively low quantity of industrial wood used by the energy sector despite the collapse of the use of coal is explained by the fact that under high CO_2 prices, other energy forms like natural gas, solar and wind energy become more and more competitive. However, the amount of industrial wood used for energy may substantially increase with subsidies for using wood for electricity and heat, even with relatively low carbon prices. With a high coal and gas price and a carbon price of 100 €/t, a subsidy of 30 €/MWh to the wood based and coal with wood co-firing electricity production will have a significant impact on the European wood based sector. Depending on the development of the market demand for

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forest industry products, such a subsidy may cause a 10–12.5% reduction in forest products production, a 6–9% increase in harvest level, about 30–60% increase in the pulpwood prices, and a 6–9 fold increase of wood imports in the EU, compared to the respective case without a subsidy in 2030.

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Introduction

In 2009, the leaders of European Union (EU) and the G8 announced an objective to reduce greenhouse gas (GHG) emissions by at least 80% below 1990 levels by 2050 in order to halt the global climatic warming to 2 °C (ECF, 2010a). On 15th of March 2012, the European Parliament adopted a non-binding resolution that supports the European Commission's "Roadmap for moving to a competitive low carbon economy in 2050" (EC, 2011a). This resolution sets intermediate reduction targets of the order of 40% by 2030 and 60% by 2040 in addition to the long run 80% emission abatement target. Before that, the EU had put in place legislation to reduce its emissions to 20% below 1990 levels by 2020. The roadmap also suggests how the sectors contributing to most of the EU emissions, i.e. power generation, industry, transport, buildings and construction, and agriculture, can transit to a low-carbon economy in a cost-effective way. The power generation industry has a special target to reduce its GHG emissions by 54–68% by 2030 and by 93–99% by 2050 compared to 1990 levels.

Studies by the European Climate Foundation (ECF, 2010a) and the European Commission (EC, 2011b) address the feasibility, challenges and implications of the 80% emissions abatement objective. The EC concluded that one of the consequences of achieving the 80% emissions abatement objective would be high CO_2 prices after 2030; over 100 €/t in 2040 and 200 €/t in 2050. In late 2011, the European Commission also published the EU Energy Roadmap 2050 Impact Assessment Report (EC, 2011c) with more detailed projections for the EU Energy sector up to 2050.

According to the ECF report (2010a), renewable energy sources (RES) are going to play a key role in achieving EU energy sector decarbonisation targets in 2050 by supplying a major part of electric power and heat. Only a minor share of energy is expected to be provided by coal and gas with carbon capture and storage (CCS). By 2030, RES energy supplies are expected to provide 55–60% of electricity, while the remainder will be provided by nuclear power, coal and gas. The use of coal and gas is expected to gradually diminish as a result of reduced CO_2 emission allowances sold on the EU Emissions Trading System (ETS) and rising CO_2 prices. However, ECF (2010b) projects the use of natural gas to increase significantly by 2030, at the same time as the use of coal – the heaviest CO_2 emitter – shrinks.

Since coal and gas are the two most important fuels used in Europe in power production, their prices and the CO_2 emission prices will affect how the new RES, including wood biomass, will compete for the share of the power market. Gas is more expensive fuel than coal, but it burns with lower CO_2 emissions.

In the near term, materialisation of the long-term projections regarding the decreased use of coal and the increased use of gas does not seem so straightforward. There has been abundant supply of CO_2 emission permits in the market in 2012 as a result of the economic downturn, and also because the EU RES directive has already spurred the member states to use increasing amounts of renewable energy. Consequently, the CO_2 prices have fallen to a very low level of about 5 €/t in October 2013. Coal prices have also decreased, due to the global economic recession and the increased use of low priced shale gas in USA to replace coal. North American coal is increasingly exported to Europe and Asia causing decreased coal prices globally. The falling prices of coal and CO_2 emission allowances are stimulating many major European power utilities to shift from gas to coal. According to Bloomberg (2012), E.ON and RWE – the biggest utilities in Germany, Europe's largest power market – are considering shutting unprofitable gas-fired plants. RWE has increased electricity from lignite coal by 20% in Germany in the first quarter of 2012. Furthermore, after the Fukushima nuclear disaster Germany decided to phase out the use of nuclear energy. Currently, there are investment plans for several new coal-fired power plants in Germany.

The EU target for reducing GHG emissions by 80% has caused strong debates among different industry groups. The Confederation of the European Paper Industries (CEPI) states in its report (CEPI, 2011) that with the increasing CO_2 prices, the forest products industries will have to compete for the wood biomass with coal plants, which will find it increasingly cost-effective to substitute wood for coal.

In this study, we examine the effects of coal, gas and carbon emission prices on the use of wood for energy and wood-based products in the EU region up to 2030. Most of the previous studies deal only with the technical and economic potentials of using wood for energy (e.g., Hansson et al., 2009), or look at the wood market implications taking either biomass prices (Moiseyev et al., 2011) or biomass use (Raunikar et al., 2010; UN, 2011) as given, or they look at the biomass scenarios without considering their market implications (Mantau et al., 2010). In the EC report (EC, 2011b), the results from the EU PRIMES energy model are fed to the agriculture and forest sector model GLOBIOM, while there is no endogenous connection between the energy and forest sectors. Few studies have looked into the interaction between the energy sector and the forest sector. Lauri et al. (2012, 2013) provide an exception and analyse the competition for wood between the forest and energy sectors, applying the EUFASOM model, with the energy sector being represented by coal and wood fired power and heat plants.

We will focus on the large-scale power and heat sector in the EU and examine the potential demand for wood fuel by the coal and wood fired power and heat plants, and how this demand depends upon different developments of the prices of fossil fuel and CO_2. Our approach is somewhat similar to Lauri et al. (2012), but the energy sector representation is expanded to cover the gas power sector, and we also take into consideration the wind and solar photovoltaic (PV) power production based on the projections of expected future capacity expansions by ECF (2010a,b). We also do a sensitivity analysis of the influence of possible decreases in future paper demand. For the analysis, we use a revised version of the partial equilibrium model for the global forest sector, the EFI-GTM model (Kallio et al., 2004). The EUFASOM model used by Lauri et al. (2012, 2013) assumes perfect foresight in the meaning that the forest industry and energy sector fully anticipate the changes in the future carbon prices and market conditions when they are making their capacity and technology choices. The EFI-GTM lacks such forward looking dynamics as the model is based on the assumption of limited foresight (Sjølie et al., 2011). On the other hand, it covers the whole world, which allows us to fully account for the international trade of wood biomass and forest products. The EFI-GTM model covers Europe at a country scale (for most of the European countries), and does not take into account more locally small-scale electricity and heat production including domestic boilers. However, the main growth in wood biomass use for energy is expected at large-scale industrial facilities (UN, 2011), where various subsidies are given in order to reach the 20% EU RES target.

Methodology

Modelling technique and main scenario assumptions

In the analysis we use the EFI-GTM global forest sector model as described in Kallio et al. (2004) and Moiseyev et al. (2011). The main revision is that we add heat and power produced from coal, gas and wood to the modelled commodities, which previously consisted of the forest and forest industry products only. We model four types of thermal power electricity generating plants (by type of fuel used – lignite, coal, gas and wood), four types of heat plants and four types of combined heat and power (CHP) plants, as described in more in detail in Section "Energy sector assumptions".

Production of electricity and heat is described as process with fixed fuel inputs and other non-fuel costs. Coal and gas inputs are exogenous with fixed costs, which can change over time according to the scenario assumptions. Wood biomass as fuel input can be obtained from logging residues, which are available as a fixed share of wood harvest, and from industrial wood (sawlogs, pulpwood and sawmill residues) converted to energy chips and wood pellets.

Availability of logging residues is defined as a share of industrial wood harvest. These shares were taken from the scenario "Promoting wood energy" in the European Forest Sector Outlook Study (EFSOS) II report (UN, 2011). In this scenario, maximum share of logging residues was applied. Costs of logging residues (delivered to the energy mill) are based on the assumptions made in the report produced for the European Environment Agency (EEA) on the "Environmentally compatible Bio-energy Potential from European Forests" (EEA, 2007). The costs of logging residues are mostly within the range 25–35 €/m^3, which is in many cases lower than the lowest cost industrial wood (pulpwood or residues from sawmills). For all scenarios, we use GDP growth assumptions from the IPCC B2 reference scenario. The other assumptions regarding forest products demand and wood supply as described in Moiseyev et al. (2011). B2 reference scenario assumes medium economic growth. In addition, we test low A2 GDP growth combined with declining graphic paper trend.

Three factors are of particular importance in the analyses – the carbon price, the price of coal and natural gas.

Regarding the price of coal and gas, we assume two future alternatives:

1. European coal prices increase linearly to 85 €/t of coal in 2020 from the present level of 70 €/t, and natural gas prices increase to 11 €/MMBtu[1] in 2020 from the current price of 8.5 €/MMBtu. These coal and gas price developments are similar to the assumptions in ECF (2010a,b).
2. European coal prices increase only modestly to 75 €/t in 2020, while natural gas price decrease moderately from the present level to 7.7 €/MMBtu by 2020. These developments could be justified, for example, by expected future export of North American shale gas.

The gas price variation relative to coal is a key factor in making a difference between two groups of scenarios with the same CO_2 price assumption.

Regarding the CO_2 emission price development, five levels from 10 to 100 €/tCO_2 in 2030 are considered:

1. Present carbon emission price level of 10 €/tCO_2 constant until 2030.
2. Low scenario: 30 €/tCO_2 in 2020 rising linearly to 40 €/tCO_2 in 2030.
3. Middle scenario: 40 €/tCO_2 in 2020 rising linearly to 60 €/tCO_2 in 2030.
4. High scenario: 40 €/tCO_2 in 2020 rising linearly to 80 €/tCO_2 in 2030.
5. Very high scenario: 40 €/tCO_2 in 2020 rising to 100 €/tCO_2 in 2030.

In all five alternatives, the present carbon emission price level of 10 €/tCO_2 is held constant until 2015, and then it rises linearly to the assumed price level in 2020. Consequently, we analyse a total of ten alternative scenarios: the high coal & gas prices case and the low coal & gas prices case combined with five CO_2 price levels.

It is assumed that Norway and Switzerland take part in the EU ETS system, and that Russia, Belarus and Ukraine within Europe and other regions outside of Europe are not going to take part in the EU ETS system. This assumption has an important impact on the price of wood in Europe and on the competitiveness of the European forest sector relative to other regions.

Energy sector assumptions

Our focus is on the question of how wood biomass will compete with coal and natural gas in the future. Since the development of the supply of solar and wind power is also expected to play a significant role during the journey of the EU towards low carbon economy, we also account for solar and wind power to a certain limited extent.

The EC Energy Roadmap 2050 (EC, 2011c) projects the electricity production to increase from some 3400 TWh in 2010 to 4100 TWh in 2030 in the reference scenario. The supply of thermal energy is projected to keep rather stable over the period 2010–2030, while in the decarbonisation scenarios, it is even projected to decline from 1900 to 2000 TWh over the period 2010–2015 to 1250–1400 TWh in 2030, mainly due to a sharp increase in wind and solar power generation. Based on that, we assume that the quantity corresponding to the current amount of electricity produced by thermal power, about 1900 TWh, must be supplied by competing gas, coal and biomass fired power plants or, up to a certain extent (about 800 TWh) by solar PV and wind power in the future. The rest of the power supply will come from hydro or nuclear power plants and also from wind and solar power. However, that part of the power supply is exogenous to our analysis. The thermal heat production is kept at its current level, but the supply is subject to competition between coal, heat and biomass fired plants. Demand for thermal electricity and heat is assumed to be inelastic.

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[1] MMBtu refers to Million British Thermal Units. 1 Btu = 1055.056 J.

The capacities of the current coal, gas and biomass fired power, heat and CHP mills in the European countries (except the Commonwealth of Independent States) are based on Platts World Electric Power Plants Database (Platts, 2012). Additional capacity for thermal energy may come on stream depending on the profitability of these investments. The current capacity and potential increases of the regional wind power and solar PV capacity are modelled in accordance to the projections by ECF (2010a), adjusting the figures for 2050 in the "Higher RES" scenario (ECF, 2010b) to the year 2030. Country-level demand for heat from CHP and district heating and electricity (gross electricity generation is used as a proxy for the demand) is based on the "EU energy trends to 2030" report (EC, 2010).

Table 1 shows assumed electricity and heat generation efficiencies for eight types of thermal power and CHP plants based on data from the database of the Global Emission Model for Integrated Systems (GEMIS, 2012). Required fuel input corresponds to the electricity efficiency and is also based on GEMIS data. The average estimate for the low heat value (LHV) of hard coal and lignite is taken from Schuster and Peterson (2002). The LHV of wood is based on United States Forest Service – Forest Products Laboratory (2004), and is assumed to be 13.76 MMBtu per tonne of air-dried wood (20% moisture content) and 12.04 MMBtu per tonne of semi-dried wood (30% moisture content). For logging residues, the latter figure is more appropriate. The average weight of wood is assumed to be 0.6 tonne/m^3 (air dry wood). Consequently, air-dried wood has an LHV of $13.76 \times 0.6 = 8.26$ MMBtu/m^3 (8.7 GJ/m^3) and semi-dried wood has an LHV of $12.04 \times 0.6 = 7.22$ MMBtu (7.6 GJ/m^3). The LHV of wood pellets is assumed to be 13.6 MMBtu per tonne (FPL, 2004). The required fuel input for coal and wood is calculated on the basis of required heat input and the LHV of the corresponding fuel, which is expressed in tonnes for hard coal and lignite and both in tonnes and cubic metres for wood. For coal with wood pellets, co-firing 20% of energy input is assumed to be coming from pellets. Natural gas is measured in MMBtu and price for gas is also expressed in value per MMBtu. Table 1 also provides the assumed CO_2 emission factors for all thermal power and CHP plants except wood fired plants, which are assumed to be CO_2 neutral. The emission factors are based on the CO_2 content of the fuels and the amounts of the respective fuels needed to produce 1 MWh of heat and/or power (fuel efficiency). For heat (district heating) plants we assume an efficiency of 0.85–0.9.

Investment and production costs for thermal power, wind and solar PV (Table 2) are based on the estimates from ECF (ECF, 2010b). The same operational and maintenance (O&M) costs were assumed for both CHP and electricity only mills. Consequently, their total costs differ only due to differences in electricity and heat efficiencies and required fuel input in terms of volume and value (based on assumed fuel price). Table 2 also shows the cost for elements other than fuel. For comparing and modelling costs of new electricity generation technologies, we have used the commonly applied Levelized Cost of Electricity (LCOE) method, and specifically the simplified LCOE method as applied in Tarjanne and Kivistö (2008). An annualised power production cost without any business profit and taxes is calculated for each power plant alternative. The annuity method is applied together with real interest rate and fixed price level. The principle of the annuity method is that the annual capital cost is calculated as equal instalments for the economic lifetime of the investment. With these instalments the investment and the interest will be paid back by the end of the economic lifetime. With a real interest rate of 5% and an economic life time of 25 years, an annuity factor (capital recovery factor – CRF) is equal to 7.1%. The annuity (CRF) factor is calculated as:

$$\mathrm{CRF} = \frac{i(1+i)^n}{(1+1)^n - 1} \tag{1}$$

where n is the economic lifetime or number of annuity periods and i is a real interest.

Table 1

Electricity and heat efficiency for power and CHP plants. Data are from the database of the Global Emission Model for Integrated Systems (GEMIS, 2012).

	Heat efficiency	Electricity efficiency	Fuel input, MMBtu/MWh	Fuel LHV, MMBtu/tonne	Fuel input, tonne/MWh	Wood fuel input m^3/MWh	CO_2 emission
Power plant, coal		0.40	9.5	25	0.38		0.9
Power, coal with pellets co-firing		0.40	7.6	25	0.30		0.7
pellets input for co-firing			1.9	13.6	0.14		
Power plant, lignite		0.40	9.5	10	0.95		1.0
Power, lignite with pellets co-firing		0.40	7.6	10	0.76		0.8
pellets input co-firing			1.9	13.6	0.14		
Power plant, gas		0.58	6.5				0.4
Power plant, wood		0.33	11.5	12	0.96	1.60	
CHP, coal	0.55	0.33	11.5	25	0.46		1.0
CHP, lignite	0.55	0.33	11.5	10	1.15		1.1
CHP, gas	0.45	0.45	8.44				0.5
CHP, wood	0.55	0.275	13.8	12	1.15	1.92	

Table 2

Electricity generation costs. Production and investment costs are from ECF (2010b).

Electricity generation technology	Capital cost, €/KW	Fixed O&M cost, €/KW	Variable O&M cost, €/MWh	Capacity load factor	Total annualised cost without fuel, €/MWh	Annualised capital costs, €/MWh	Non-fuel O&M Cost, €/MWh	Fuel, €/MWh	Total costs, €/MWh	CO2 emission factor	Cost of electricity generation			
											CO_2 40 €/tonne	CO_2 60 €/tonne	CO_2 80 €/tonne	CO_2 100 €/tonne
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Coal conventional	1400	20	1	0.86	16.8	13.2	3.7	26	42.8	0.9	79	97	115	133
Coal co-firing (pellets)	1400	20	1	0.86	16.8	13.2	3.7	42	59	0.7	88	102	116	130
Gas conventional	700	15	1	0.6	13.3	9.4	3.9	50	63.3	0.4	79	87	95	103
Wind onshore	1400	35	0	0.3	51.1	37.8	13.3	0	51	0	51	51	51	51
Wind offshore	2560	40	0	0.37	68.4	56.0	12.3	0	68.4	0	68	68	68	68
Solar PV	1550	15	0	0.12	118.9	104.6	14.3	0	118.9	0	119	119	119	119
Wood	2700	13	9	0.8	38.2	27.3	10.9	58	96.2	0	96	96	96	96

Table 3
Annual electricity production in the EU region (with Norway & Switzerland) in 2030, GWh.

Price for CO_2 in 2030, euro/tonne	Gas	Coal	Coal & wood co-firing	Wood	Wind & Solar
CO_2 price in 2030	Low coal & gas prices				
10 €/t	757,822	1,075,950	0	63,149	17,151
40 €/t	1,097,300	354,436	0	99,809	361,903
60 €/t	1,224,777	144,417	0	109,892	434,000
80 €/t	1,359,182	8,008	952	110,623	434,000
100 €/t	1,340,555	7,956	753	111,908	451,257
CO_2 price in 2030	High coal & gas prices				
10 €/t	368,408	1,165,403	0	73,084	306,624
40 €/t	408,625	968,743	0	101,540	434,000
60 €/t	530,558	829,573	0	117,745	434,480
80 €/t	962,031	280,023	0	119,255	550,611
100 €/t	762,547	153,627	755	128,845	866,602

Total annualised electricity generation cost is calculated according to Eq. (2):

$$\mathrm{LCOE} = \frac{\mathrm{Capital\_cost} \times \mathrm{CRF} + \mathrm{Fixed\_O\&M\_cost}}{8.76 \times \mathrm{Capacity\_load\_factor}} + \mathrm{Variable\_O\&M\_cost} + \mathrm{Fuel\_cost} \tag{2}$$

Column F (Table 2) shows total annualised electricity generation cost without fuel cost. For wind and solar PV power fuel is not required, consequently these costs estimates are final. For the solar PV power these estimates are given from ECF (2010b) as averaged between 2020 and 2030.

The fuel costs assumed in the study are compared in column I of Table 2.The costs are based on the low coal & gas price scenario's fuel prices assumptions and required fuel input from Table 1. For biomass power and CHP generating technologies, the fuel cost will be the key factor. To complement this cost comparison, different CO_2 prices in the range of 40 to 100 €/tCO_2 are assumed and resulting electricity costs are shown in columns L-O. It is seen in column J that, without CO_2 allowances, coal power is the cheapest, onshore wind is the second cheapest, and gas is the third cheapest; wood fired power is substantially more expensive. Only coal fired power sector is able to produce electricity below the present market price (45–50 €/MWh), which reflects the current situation in the EU. However, if we deduct annualised capital costs from total electricity costs, then existing coal power mills (without investment related debts) can make a substantial profit margin above 15 €/MWh, while gas-fired plants cannot break-even, again reflecting the current situation in Europe. A CO_2 price of 40 €/tCO_2 is needed to make market conditions equal for coal and gas (see column L, Table 2). Wood based electricity cost may become equal to coal with 60 €/tCO_2 assumption and with 80 €/tCO_2 wood will be on an equal footing with gas-fired power. This unfavourable situation for wood energy may change with 100 €/tCO_2, but wind power will benefit a lot with such extremely high CO_2 permit prices.

However, in this section we only examined the most basic assumption reflecting the current market situation in Europe. The cost data in Table 2 in relation to various CO_2 prices, gives a simplified indication of the competitiveness of the electricity production technologies. CHP mills can sell the heat, which let them offset electricity costs, and we need to examine different cases with coal and gas price development to model the interactions between the electricity and heat markets.

Results

Shares of the electricity production in the EU region

Allocation of the annual electricity production in 2030 under alternative scenarios is shown in Table 3. Under the low coal & gas prices scenario with 40 €/tCO_2, the competition takes place mainly between coal and gas – with gas taking a major share in electricity production. Wood-fired CHP takes a modest share of 5%. Under the 60 €/tCO_2 scenario, the share of coal powered plants shrinks to supply just a tiny bit more than wood-fired power plants, and wood-fired power expands marginally from 5% to 5.5%. Under the 80 €/tCO_2 scenario, coal power is practically driven out of markets due to relatively low gas prices and high carbon emission prices. Under the low coal & gas prices scenario most of the competition takes place between coal and gas, with a slowly increasing competition from wind and solar PV production, while the wood-fired power sector is stuck below 6% share.

Under the high coal & gas prices scenario with 60 €/tCO_2, coal is still a major supplier of electricity (44%), but dropping to 15% only under 80 €/tCO_2 scenario, while wood-fired power provides around 6.2% of the total. Higher coal and gas prices coupled with a carbon price of 100 €/tCO_2 results in a price of electricity exceeding 120 €/MWh in 2030, which allows solar PV power to enter the electricity market more actively. Both coal and gas power shares go down with gas power still keeping a high 40% share, while coal has only an 8% share. A high electricity price also favours wood-fired electricity to a limited extent, whose share increases up to 6.8%. Hardly any co-firing of wood with coal takes place.

Table 4 shows more detailed data regarding electricity and heat production in 2030 by different type of wood-fired energy mills under the high coal & gas prices assumption and different levels of CO_2 prices. The CHP mill produces both electricity and heat in the most efficient way. Dedicated heat mills are economical with the current low CO_2 prices, but they contribute only 6.5% of the total heat supplied by wood-fired mills. Dedicated wood-fired power mills may supply up to one-third of the total electricity supplied by wood-fired plants; however, with rising CO_2 prices this share goes down to less than 1%. CHP wood-fired mills with the high CO_2 prices will produce majority of electricity and heat. Despite a low share (<7%) of wood-fired electricity, wood-based heat is projected to go up to 31% of the total heat provided by the medium- to large-scale energy sector. Use of wood biomass is projected to increase from 151 million m^3 to 256 million m^3 with increasing CO_2 prices. While most of these volumes will come from the lowest costs logging residues, a significant share 32 million m^3 may come from industrial wood sources with the high CO_2 prices of 100 €/tCO_2.

The main result is that wood-fired electricity is able to gain only a marginal market share due to limited availability of low-cost wood from logging residues. Industrial wood starts to be used increasingly only with higher coal and gas prices and with very high carbon emission prices of 100 €/tCO_2. With carbon emission prices well above 100 €/tCO_2, more wood biomass will become available for energy. While looking at the current situation, such carbon prices seem very high, but such prices might occur if the low carbon Europe roadmap becomes a reality (EC, 2011b,c).

The use of industrial wood for energy could be higher under different forest sector market developments and in the presence of additional policies that stimulate faster introductions of renewable energy sources. The main instrument for stimulating acceleration of renewable energies in the EU has been feed-in tariffs. In addition, investment subsidies, extra bonuses and renewable obligation certificates are used to stimulate use of renewable raw materials in electricity production. So far, we analysed the competition in the EU electricity and heat markets with different carbon emission prices set by the EU ETS system. Additional subsidies were not considered, although given the currently low CO_2 prices, these subsidies could play a more important role. Therefore, we will try to provide some insights into the potential effects of subsidies for use of wood in the power sector. We also address the effect that reduced graphic paper consumption might have on the use of industrial wood for energy.

The impact of subsidies for wood-based electricity on the use of wood for energy

We include subsidy (compensation) for wood-fired electricity produced at power and CHP mills by specifying an additional compensation for the production costs at the level of 30 €/MWh of electricity (which is just a bit higher than the lowest level of “NawaRo” bonus in Germany for power production using solid renewable biomass (BMELV, 2009).

In addition, we assume 30 €/MWh as a compensation for co-firing wood and wood pellets with coal. This level is nearly 50% lower than the present renewable obligation certificate in the UK of about 55 euros. High-level subsidies are also used for wood with coal co-firing in the Netherlands and Denmark. We assume a more modest level of coal co-firing subsidy at the EU level from 2020. This level of compensation will barely cover annualised capital costs for a new wood-fired power/CHP mill (Table 2). However, this level of compensation will cover higher wood fuel costs and provide an extra bonus for the existing coal powered mills. These subsidies will increase the relative competitiveness of wood-fired power mills and especially for co-fired coal and wood energy production.

Table 4
Annual electricity and heat production in the EU region (with Norway & Switzerland) by wood-fired plants in 2030 under high coal & gas prices scenario.

Price for CO_2 in 2030, euro/tonne	CHP		Power only	Heat only	Total wood-fired		Wood, million m^3	
	Electricity, GWh	Heat, MMBtu	Electricity, GWh	Heat, MMBtu	Electricity, GWh	Heat, MMBtu	Wood biomass use total	Industrial wood use
10	72,405	506,832	680	35, 471	73,085	542,303	151	0
40	86,186	603,303	15,354		101,540	603,303	200	4
60	87,848	614,933	29,897		117,744	614,933	229	8
80	108,821	761,747	10,434		119,255	761,747	236	14
100	128,184	897,289	661		128,845	897,289	256	32

Table 5
Annual electricity production in the EU region (with Norway & Switzerland) in 2030, GWh with high coal and gas prices scenario.

Fuel type	Without subsidy	Subsidy 30 euro/MWh
CO_2 price 40 euro/tCO_2		
Coal	968,743	28,006
Coal co-firing	0	970,452
Gas	408,625	361,896
Wood (logging residues)	99,404	118,249
Wood (industrial wood)	2136	429
Wind & solar	434,000	434,000
CO_2 price 100 euro/tCO_2		
Coal	153,627	0
Coal co-firing	755	694,974
Gas	762,547	288,040
Wood (logging residues)	112,000	116,475
Wood (industrial wood)	16,845	5674
Wind & solar	866,602	806,653

Table 5 shows the results for the electricity generation in 2030 for the high coal & gas prices scenario under two different CO_2 price levels with and without subsidies. With the assumed 30 €/MWh subsidy and a carbon price of 40 €/tCO_2, the most striking result is that the subsidy helps to maintain coal power share to a large extent, while it increases the use of wood for wood-fired mills only modestly. It seems that the subsidy can boost the use of wood for energy much more than by increasing carbon price. This may explain why at present in some countries substantial quantities of industrial wood is used for power production besides forest residues, even with rather low carbon prices. In addition, there are other possible reasons for using industrial wood (mainly pulpwood and residues from sawmills) for power production, like falling pulpwood prices caused by the long economic recession or declining paper demand, as discussed later.

Subsidies will increase use of wood for energy in 2030 mainly by increasing the use of industrial wood, while use of logging residues increases only marginally, since the supply of logging residues is limited by harvest levels. An extra source of industrial wood comes to the energy sector by diverting wood from the wood-based sector, which is hurt by increasing wood prices and especially electricity prices under higher carbon price levels. Additional wood is also increasingly imported from other regions with increasing carbon prices and subsidies. Industrial wood price development and wood imports are analysed in Section “The impact of reduced graphic paper consumption and lowering global economic growth on the use of wood for energy”.

It is important to note that subsidies for wood-fired and especially coal with wood co-fired mills substantially increase the use of wood and especially industrial wood for energy. Consequently, wood displaces both coal and gas from the electricity markets. However, with the low carbon prices (40 €/tCO_2) wood will displace mostly gas-fired power mills because carbon prices are too low to drive coal out of the market, and gas power is much more vulnerable under the assumption of higher gas prices. Perhaps this could explain why major European power sector companies are planning to downsize their gas-fired mills contrary to the general strategy by the European Commission to increase the use of gas and reduce use of coal in the medium term (until 2030). It will require much higher carbon prices to get coal and gas on a more equal footing. Increased carbon prices and subsidies for wood seems to influence rather strongly the distribution between coal and gas. However, even with a high 100 €/tCO_2 price and subsidy, mostly gas-fired electricity is projected to be displaced by increasing use of industrial wood, which is not beneficial regarding reducing the high CO_2 emission from power production using coal. In addition, the model results show that the main sources of the growing use of industrial wood for energy are imports from the regions outside of the EU, which thus creates considerable carbon leakages.

Table 6
Annual electricity production in the EU region (with Norway & Switzerland) in 2030, GWh with high coal and gas prices under A2 reference GDP growth and declining graphic paper consumption.

Fuel type	Without subsidy	Subsidy 30 euro/MWh
CO_2 price 40 euro/tCO_2		
Coal	970,821	28,023
Coal co-firing	0	1,053,109
Gas	404,840	280,516
Wood (logging residues)	95,497	115,473
Wood (industrial wood)	7,749	1,695
Wind & solar	434,000	434,000
CO_2 price 100 euro/tCO_2		
Coal	99,871	0
Coal co-firing	42,748	767,700
Gas	749,277	262,118
Wood (logging residues)	109,707	115,473
Wood (industrial wood)	41,694	28,036
Wind & solar	868,303	738,488

The impact of reduced graphic paper consumption and lowering global economic growth on the use of wood for energy

The present economic situation in the EU with its debts problems and generally low GDP growth (varying between EU member countries between negative to low GDP growth) combined with the overall global economic slowdown may have a long lasting effect on the medium-term economic growth. To consider this possible alternative general economic condition, we use the IPCC A2 reference scenario with its GDP of about 75% of the B2 reference scenario GDP in 2030. In addition, over the last 10–15 years, there has been a decline in graphic paper consumption in the USA (Ince and Nepal, 2012). This trend is also likely to occur in Western European, mainly as a result of competition with electronic media. We wanted to test how sensitive such a decline could be for increasing the potential supply of industrial wood for energy. Our assumption regarding future graphic paper consumption in 2030 is that in North America and the EU, it will be about 50% of the consumption level in 2010, and that in other regions consumption will not grow from the present level. The other paper and paper board demand is assumed to grow in the same proportion to the GDP growth as in the main scenarios, but the GDP growth according to A2 reference scenario will be slower. Overall, the paper demand in 2030 will be about 200 million tonnes less under the A2 reference GDP growth and reduced graphic paper consumption than under the B2 GDP growth and paper growth in line with the past growing trend. As a result, less demand for wood pulp and lower future pulpwood prices increase the use of industrial wood for energy.

Table 6 shows projected electricity generation in 2030 for the high coal & gas price scenario under different CO_2 price levels with A2 reference GDP growth without subsidy for wood-fired electricity and coal with wood co-firing, and with a subsidy of 30 €/MWh. These results shows that without subsidies, the amount of industrial wood used for electricity is moderate (14 million m^3) with CO_2 price of 40 €/tCO_2, but it increases up to 88 million m3 in 2030 with CO_2 price of 100 €/tCO_2, which is 2.5 times more than with the same CO_2 price but with higher paper demand (see Table 5). The subsidy for wood firing and co-firing increases the amount of industrial wood used for electricity up to 315 million m^3 with a CO_2 price of 40 €/tCO_2 and 280 million m^3 with a CO_2 price of 100 €/tCO_2 in 2030. Most of this wood will be used in coal with wood and pellets co-fired power mills, while use of industrial wood by wood-fired mills will be somewhat lower compared to the no-subsidy case.

Under the conditions when economic growth and paper demand is weakening, use of industrial wood for energy may substantially increase, but this will require high carbon prices. However, the subsidy for wood-fired and coal with wood co-firing power will be a major force in driving the increase of the industrial wood use for energy; a weakening demand for forest products will give an additional boost to this process.

Table 7
Projected change of the use of industrial wood for energy by source under high coal and gas price case in 2030 and 100 €/tCO$_2$ relative to the high coal and gas price in 2030 and 10 €/tCO$_2$, million m^3.

Subsidy for wood energy	Pulp	Sawnwood	Panels	Total from wood products	Additional imports	Additional harvest	Total
Industrial wood for energy by source under B2 economic growth							
No subsidy	7	1	4	11	10	8	30
Subsidy 30 euro/MWh	23	4	15	42	173	25	241
Industrial wood for energy by source under A2 economic growth and declining graphic paper demand							
No subsidy	18	1	8	26	35	23	84
Subsidy 30 euro/MWh	30	3	18	51	186	38	275

Use of wood for energy and wood based products

Table 7 shows the projected increase of wood use for energy and corresponding sources from the reduction of wood used for wood pulp, sawnwood, wood-based panels, imports and additional harvests under scenarios studied in the previous sections. The high coal & gas price case was used in these scenarios, because practically no industrial wood is used for energy under the low coal & gas price case, and the use of logging residues for energy has no impact on the forest sector in Europe. Higher coal prices, and especially high gas prices, combined with a very high CO$_2$ price of 100 €/t results in 30.2 million m^3 of wood used for energy production. This causes a reduction of 6.8 million m^3 wood used for wood pulp, and a reduction of 4 million m^3 used for wood-based panels. The total 11.5 million m^3 reduction in 2030 compared to the Low scenario is only 2%. The additional 10.3 million m^3 of industrial wood for energy comes from increased imports to the EU, which in 2030 increases from 36.6 million m^3 in the Low price scenario to 46.3 million m^3 in the High price scenario. The remaining 8.5 million m^3 of industrial wood come from additional harvesting (compared to the Low carbon price scenario). With a subsidy level of 30 €/MWh the total amount of industrial wood used for energy is eight times more than the amount without subsidy. In the latter case reduction of wood for wood based products is almost four times more than without subsidy, additional harvests are three times higher, and imports are 17 times higher compared to the no-subsidy case. Subsidy for firing wood will mainly hit the pulp and panel industries; however, sawnwood will also get some reduction.

The same trends are observed under the alternative scenario with reduced graphic paper demand and lower GDP growth, but the total levels of industrial wood used for energy is somewhat higher and additional harvest is substantially higher. The model results show that without subsidies, imports of wood to the EU region mainly come from Russia. With the subsidy North America becomes the biggest exporter of wood for energy, which will mainly be traded in the form of wood pellets. Russia and Latin America will be the second and third largest exporters of wood pellets and wood chips for energy.

Fig. 1 shows the projected development of the industrial wood harvest in the EU region with the different CO$_2$ price levels without subsidies and with a 30 €/MWh subsidy (assumed for the 100 €/tCO$_2$ case). The chart on the left shows harvest development under the main scenario (paper demand continues with the past growth). It can be clearly seen that the harvest level is mainly affected by subsidies for the wood-fired and coal with wood co-fired power, and that increasing CO$_2$ price has a minor effect on increasing industrial wood harvest. Nevertheless, under the alternative scenario with the weakening paper demand (Fig. 1, right chart), the high CO$_2$ price of 80–100 €/tCO$_2$ has a substantial effect on the increased harvest in 2030, and the subsidy for the wood-based power has an even stronger effect both in the long term, but especially in the short term.

Fig. 2 shows development of the industrial wood used for wood-based products (totals) under different alternative scenarios. Increasing carbon prices have a modest impact on the amount of wood used by EU forest products industries, however this becomes much more substantial with a very high carbon price and weakening forest products demand. A subsidy of 30 €/MWh for wood firing and co-firing with coal will cause the most dramatic reduction of wood used for forest products.

Fig. 3 shows the projected pulpwood price development in the EU region. The chart on the left shows harvest development under the main scenario. Increasing CO$_2$ price up to 100 €/tCO$_2$ affect the pulpwood price only marginally, while a subsidy for energy has a much more dramatic effect. The

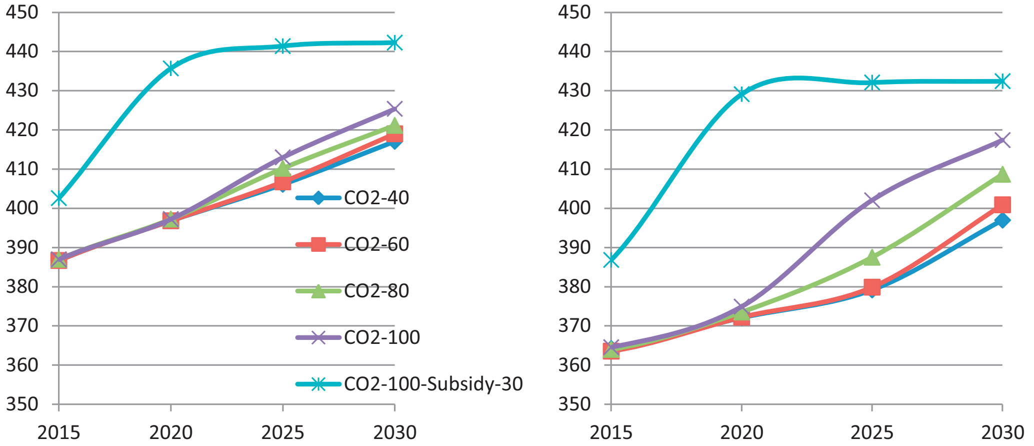

Fig. 1. EU region (with Norway and Switzerland) projected industrial roundwood harvest development under the high coal & gas prices (left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline), *Y*-axis – harvest, million m^3.

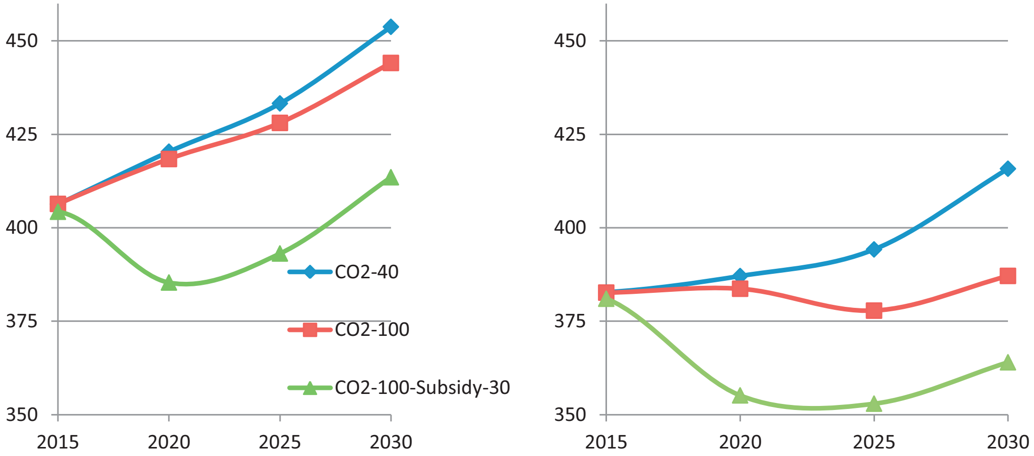

Fig. 2. EU region (with Norway and Switzerland) projected industrial wood use for forest products development under the high coal & gas prices (left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline), *Y*-axis – wood use, million m^3.

same trend is also seen in the chart on the right for the alternative paper demand scenario, except that increasing carbon price has a more substantial effect in the long run.

Overall, under the main scenario with the paper demand growing in line with the long-term past trend, increasing carbon emission prices up to the very high 100 €/tCO_2 level combined with the high coal and gas prices have a relatively marginal impact (about 2% reduction in 2030) on the wood-based industry production and a marginal impact on EU harvest (2% increase in 2030). A subsidy of 30 €/MWh to the wood-based energy sector will have a much more pronounced impact on the European wood-based industry: there is a 10–12.5% reduction in 2030 relative to the low carbon price scenario without subsidy, depending on the paper demand development, a 6–9% increase in harvest level in 2030, about a 30–60% increase in the pulpwood prices, and EU wood imports will grow by 6–9 times (see Fig. 4). Additional wood imports are projected mostly from North America, Russia and Latin America mainly in the form of wood pellets and wood chips.

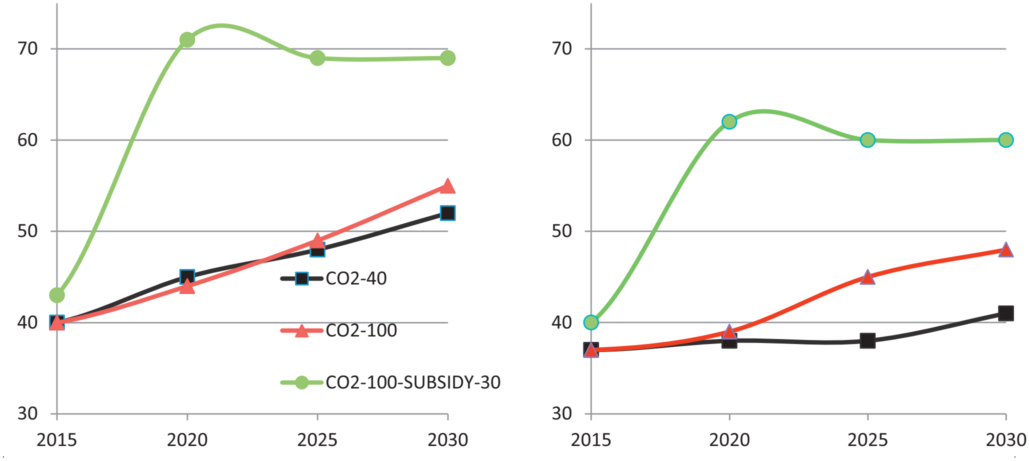

Fig. 3. EU region (with Norway and Switzerland) projected pulpwood price development under the high coal & gas prices (left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline), *Y*-axis – price, €/m^3.

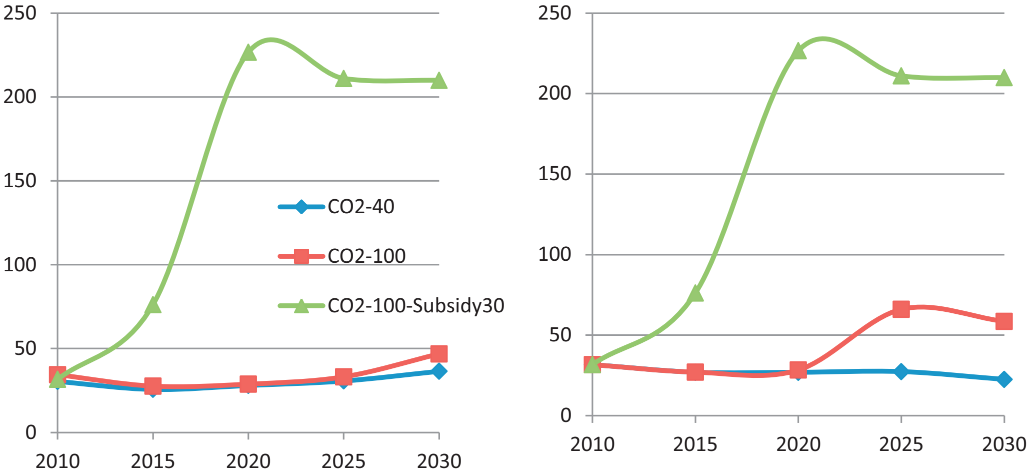

Fig. 4. EU region (with Norway and Switzerland) projected industrial wood imports development under the high coal & gas prices (left chart: B2 GDP growth, right chart: A2 GDP growth with the assumed graphic paper demand decline), *Y*-axis – imports, million m^3.

Discussion and conclusions

We studied production of wood based electricity and heat under different levels of coal, gas and carbon emission prices and varying market conditions. With low coal and gas prices, coal is practically displaced out of market with the CO_2 price of 80 €/t. However, wood-based electricity is then limited to the use of low cost logging residues, and its share is about 2.7% of the total of 4100 TWh electricity generation in EU in 2030 (EC, 2011c). With higher coal and especially gas prices coal is projected to be displaced from the market completely only with carbon price well above 100 €/tCO_2. Up to 80 €/tCO_2, production of wood-based electricity does not increase much. It takes a carbon price of up to 100 €/tCO_2, before wood-based electricity production reaches 3.1% of the total market in 2030. Then some 32 million m^3 of industrial wood in addition to 224 million m^3 of logging residues will be used to produce electricity and heat.

An EC report (2011b) estimates that the use of forest biomass for energy will increase by a modest 27% (11 Mtoe[2] – about 40 million m^3 of wood) over the period 2005–2030. The report is based on the EU PRIMES energy model linked to the GLOBIOM model which simulates supply of agriculture and forest biomass. The report projects that the agricultural biomass supply for energy will increase by 85 Mtoe and that waste biomass supply will increase by 38 Mtoe over the period 2005–2030. The share of wood biomass from the total biomass use will drop to 25% from the current 50%. The report points out that there is a rather high uncertainty related to the agricultural and forestry biomass supply. In the EFI-GTM model, only wood-based electricity and heat production is currently modelled within the thermal power sector. Inclusion of agricultural and waste biomass supply would decrease the share of wood-based power, the magnitude of that impact depending on the relative competitiveness of wood versus agricultural biomass. The ECF report (2010b) projects the biomass-waste share to be at 10% in 2030 (410 TWh), while our estimate for 80 €/tCO_2 and high coal & gas price scenario (similar assumption as in the ECF report) suggests a share of 2.9% for wood biomass only (119 TWh). This means there is a 29% share for electricity from wood biomass in the total electricity production from biomass (410 TWh). Our wood energy share estimate is somewhat higher than the EC report (2011b) estimate, but this is consistent with the EC report considering the high uncertainty of both estimates of the share of wood-based power and lower carbon price around 40–50 €/tCO_2 in 2030 (EC, 2011b).

Using EU ETS as a main market instrument, only limited amounts of industrial wood are used for energy even under high 100 €/tCO_2 price, and forestry wood biomass for energy supply mostly comes from logging residues. In that setting, the average price of pulpwood in Europe reaches 55 €/m^3. This is in line with the EEA (2007) and Moiseyev et al. (2011), who found supply of wood biomass for energy to be limited to logging residues with the energy wood price below 50 €/m^3, and at 60 €/m^3 the supply of industrial wood for energy was also marginal. With the price above 70 €/m^3, energy wood supply was substantially increased. However, even with the CO_2 price of 100 €/t, the energy sector is not ready to pay prices much higher than 55 €/m^3 for wood, because then the other options for producing energy, such as gas-fired energy, solar PV and wind power become more competitive. Also the supply of agricultural biomass including energy crops and short-rotation crops can be increasingly supplied for energy at a lower price point. This implies that the share of wood in the total biomass for energy supply may decline in the future.

However, a firm conclusion that use of industrial wood for energy will always be limited to a modest quantity cannot be made. This is because several EU countries support the use of wood biomass for heat and electricity also by other policy instruments than EU ETS, like feed-in tariffs and various kinds of premium bonuses and subsidies. We did not analyse feed-in tariffs, which are difficult to tackle with partial equilibrium models. However, premium bonuses commonly used in some of the EU countries were considered in our study. Even a relatively modest subsidy or bonus of 30 €/MWh for electricity generation (3 eurocents/kWh) leads to a substantial increase in the use of industrial wood use for energy even under a modest carbon price. We also found that such an increase may magnify, if there is a simultaneous decline in the use of pulpwood in the forest industry due to the weakening paper demand in Europe and to some extent globally. These energy wood subsidies can boost the demand for wood for electricity and heat more than increasing carbon emission prices. However, they are not cost-efficient from the point of view of reduction of the emissions in the whole energy sector. Depending on coal, gas and CO_2 prices, boosting the use of wood for energy with subsidies can lead to lower displacement of coal and higher displacement of gas, which produces less CO_2 emissions than coal. It would be more efficient to increase CO_2 prices than to use subsidies for wood-based energy. Nevertheless, considering the fact that subsidies for the use of woody biomass for energy are widely used, it would be worth to examine them further in the future studies. Here, we did not examine different options like specific subsidies for using logging residues or wood biomass from short-rotation wood plantations.

One of the shortcomings in this study is that we excluded agricultural biomass and short rotation woody crops from the analysis. While they can complement woody biomass in the energy palette (which would thus lead to higher total biomass share), they also compete with wood biomass to some extent. Thus the demand for woody biomass in heat and power production could be smaller than what was projected by us. Also, we ignored the future bio-refinery technologies producing liquid biofuels from woody biomass and black liquor. Including them in the analysis would probably increase the total use of wood for energy, although part of the wood going for bio-refineries would be redirected there from heat and power plants in such setting (Kallio et al., 2011).

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[2] Million tonnes of oil equivalent (Mtoe); 1 toe ≈ 41.86 GJ (Gigajoule).

Heat and power production was implemented in the EFI-GTM model in a simple manner. Nevertheless, the model provides the results consistent with other studies using dedicated energy models (ECF, 2010b; EC, 2011b). Yet, in several previous studies (Moiseyev et al., 2011; Raunikar et al., 2010; UN, 2011) considering the linkages of wood and energy sectors, one has typically made exogenous assumptions regarding either the price or the demand for woody biomass for energy. Our approach, even if simplified, allowed us to endogenize the demand for energy wood and to examine consistently the impacts of policy instruments such as carbon price and subsidies for energy generation on the wood market and on the volume of wood biomass used for heat and power. This opens new interesting applications of the forest sector modelling which we intend to pursue in future studies.

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